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Jon Lee · Giovanni Rinaldi
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Combinatorial Optimization

5th International Symposium, ISCO 2018
Marrakesh, Morocco, April 11–13, 2018
Revised Selected Papers

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Preface

This volume contains the regular papers presented at ISCO 2018, the 5th International Symposium on Combinatorial Optimization, held in Marrakesh, Morocco during April 11–13, 2018. ISCO 2018 was preceded during April 9–10 by the Spring School on "Advanced Mixed Integer Programming Formulation Techniques" given by Juan Pablo Vielma and Joye Huchette (MIT, USA). ISCO is a new biennial symposium. The first edition was held in Hammamet, Tunisia, in March 2010, the second in Athens, Greece, in April 2012, the third in Lisbon, Portugal, in March 2014, and the fourth in Vietri Sul Mare, Italy, in May 2016. The symposium aims to bring together researchers from all the communities related to combinatorial optimization, including algorithms and complexity, mathematical programming, operations research, stochastic optimization, multi-objective optimization, graphs, and combinatorics. It is intended to be a forum for presenting original research on all aspects of combinatorial optimization, ranging from mathematical foundations and theory of algorithms to computational studies and practical applications, and especially their intersections.

In response to the call for papers, ISCO 2018 received 75 regular submissions. Each submission was reviewed by at least three Program Committee (PC) members with the assistance of external reviewers. The submissions were judged on their originality and technical quality and the PC had to discuss in length the reviews and make tough decisions. As a result, the PC selected 35 regular papers to be presented in the symposium giving an acceptance rate of 46% (69 short papers were also selected from both regular and short submissions). Four eminent invited speakers, Friedrich Eisenbrand (EPFL, Lausanne, Switzerland), Marica Fampa (Federal University of Rio de Janeiro, Brazil), Bernard Gendron (University of Montreal, Canada), and Franz Rendl (University of Klagenfurt, Graz, Austria), also gave talks at the symposium. The revised versions of the accepted regular papers and extended abstracts of the invited talks are included in this volume.

We would like to thank all the authors who submitted their work to ISCO 2018, and the PC members and external reviewers for their excellent work. We would also like to thank our invited speakers as well as the speakers of the Spring School for their exciting lectures. They all much contributed to the quality of the symposium.

Finally, we would like to thank the Organizing Committee members for their dedicated work in preparing this conference, and we gratefully acknowledge our sponsoring institutions for their assistance and support.

May 2018

Jon Lee
A. Ridha Mahjoub
Giovanni Rinaldi

The original version of the book frontmatter was revised: The second editors' affiliations have been corrected. The correction to the book frontmatter is available at https://doi.org/10.1007/978-3-319-96151-4_36

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Plenary Lectures

Proximity Results and Faster Algorithms for Integer Programming Using the Steinitz Lemma

Friedrich Eisenbrand

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We consider integer programming problems in standard form $max\{cTx : Ax = b, x \geq 0\ , x \in Z^n\}$ where $A \in Z^{m \times n}$, $b \in Z^m$ and $c \in Z^n$. We show that such an integer program can be solved in time $(m\delta)O(m) \cdot ||b||_{\infty}^{2}$, where δ is an upper bound on each absolute value of an entry in A. This improves upon the longstanding best bound of Papadimitriou (1981) of $(m \cdot \delta)^{O(m^2)}$, where in addition, the absolute values of the entries of b also need to be bounded by δ. Our result relies on a lemma of Steinitz that states that a set of vectors in R^m that is contained in the unit ball of a norm and that sum up to zero can be ordered such that all partial sums are of norm bounded by m. We also use the Steinitz lemma to show that the ℓ_1-distance of an optimal integer and fractional solution, also under the presence of upper bounds on the variables, is bounded by $m \cdot (2m \cdot \delta + 1)^m$. Here δ is again an upper bound on the absolute values of the entries of A. The novel strength of our bound is that it is independent of n. We provide evidence for the significance of our bound by applying it to general knapsack problems where we obtain structural and algorithmic results that improve upon the recent literature.

Challenges in MINLP: The Euclidean Steiner Tree Problem in $\mathbb{R}^n$

Marcia Fampa

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The Euclidean Steiner Tree Problem (ESTP) is to find a network of minimum length interconnecting p points in $\mathbb{R}^n$, known as terminals. Such network may be represented by a tree, where the nodes are given by the terminals, and possibly by additional points, known as Steiner points. The length of the network is defined as the sum of the Euclidean lengths of the edges in the tree. Without allowing Steiner points, the problem is the easily solved Minimum Spanning Tree Problem, nevertheless, the possibility of using Steiner points, makes its solution very difficult, particularly when n is greater than 2.

An interesting feature about the ESTP is its history. It traces back to the 17th century when the French mathematician Pierre de Fermat proposed a challenge where three points were given in the plane, and the goal was to find a fourth point such that the sum of its distance to the three given points was at minimum. The challenge was solved with the works of Torricelli (1640), Cavalieri (1647) and Heinen (1834). Two generalizations of Fermat's challenge were later presented in the famous book "What is mathematics?", by Courant and Robbins (1941). The first is the problem of finding a point such that the sum of its distance to p given points is at minimum, which was introduced as the Fermat Problem. The second generalization is the ESTP.

The solution of Fermat's challenge made it possible to identify important properties satisfied by an optimal solution of the ESTP, a Steiner Minimal Tree (SMT). These properties have been used in the construction of mathematical models and algorithms for the problem. Maculan, Michelon and Xavier (2000) presented a mixed integer nonlinear programming (MINLP) formulation for the ESTP. The formulation (MMX) describes topologies of SMTs with linear constraints and binary variables, which indicate the edges in the tree. The objective function of the model is a non-convex function on the binary variables and also on continuous variables that represent the position of the Steiner points. Even though a great improvement was observed on the performance of global-optimization solvers in the last decade, the results that we obtain when applying well known solvers, such as Scip and Couenne, to MMX are frustrating.

In this work, we are interested in identifying characteristics of the ESTP that make it such a great challenge for MINLP solvers. By identifiyng these characteristics, we propose alternative formulations with the objective of modeling it as a convex problem, strengthening the formulation with the development of valid inequalities, eliminating isomorphic topologies present in the feasible set of MMX, and handling the non-differentiability of the square root used in the computation of the Euclidean distance. We finally note that these characteristics are also found in other optimization problems, especially with geometric properties, and we use them not only to advance in the numerical solution of the ESTP, but also to point directions for improvements on MINLP solvers. Motivated by our smoothing strategy for the square root, for example, a new feature was incorporated into Scip, for handling piecewise-smooth univariate functions that are globally concave.

Lagrangian Relaxations and Reformulations for Network Design

Bernard Gendron

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We consider a general network design model for which we compare theoretically different Lagrangian relaxations. Fairly general assumptions on the model are proposed, allowing us to generalize results obtained for special cases. The concepts are illustrated on the fixed-charge multicommodity capacitated network design problem, for which we present different Lagrangian relaxations: the well-known shortest path relaxation (that decomposes by commodity) and knapsack relaxation (that decomposes by arc), and new relaxations that decompose by node. Three such node-based relaxations are presented: the first one is based on a partial relaxation of the flow conservation equations, the second one is based on the same relaxation, but also uses Lagrangian decomposition (also called variable splitting), while the third one exploits solely Lagrangian decomposition. We show that these three new relaxations define Lagrangian duals that can improve upon the linear programming relaxation bounds, contrary to the shortest path and knapsack relaxations, which provide the same lower bound as the linear programming relaxation. Dantzig-Wolfe reformulations are derived for each of these Lagrangian relaxations and bundle methods are proposed for solving these reformulations. The different Lagrangian relaxations are also used as a basis for developing Lagrangian matheuristics that solve restricted mixed-integer linear programming models, including intensification and diversification mechanisms. Computational results on a large set of benchmark instances are presented, demonstrating that the node-based Lagrangian relaxation bounds are significantly better than linear programming relaxation bounds and that the Lagrangian matheuristics are competitive with state-of-the-art heuristic methods for the fixed-charge multicommodity capacitated network design problem.

Order Through Partition: A Semidefinite Programming Approach

Franz Rendl

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Ordering Problems on n objects involve pairwise comparison among all objects. This typically requires $\binom{n}{2}$ decision variables.

In this talk we investigate the idea of partitioning the objects into k groups (k-partition) and impose order only among the partition blocks.

We demonstrate the efficiency of this approach in connection with the bandwidth minimization on graphs. We consider relaxations of the partition model with the following characteristics:

(1) The weakest model is formulated in the space of symmetric $n \times n$ matrices and has the Hoffman-Wielandt theorem in combination with eigenvalue optimization as a theoretical basis.

(2) We also consider semidefinite relaxations in the space of $n \times n$ matrices, involving k semidefinite matrix variables. The idea here is to linearize the quadratic terms using eigenvalue decompositions.

(3) Finally, the strongest model is formulated in the space of symmetric $nk \times nk$ matrices. It is based on the standard reformulation-linearization idea.

We present theoretical results for these relaxations, and also some preliminary computational experience in the context of bandwidth minimization.

Co-authors: Renata Sotirov (Tilburg, Netherlands) and Christian Truden (Klagenfurt, Austria)

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